the eggs of *Triton* in the two-celled stage, his method permitting of different degrees of constriction and of constriction in different planes, as well as a thorough study of the resulting abnormalities; and by E. B. Wilson, who gave the results of his studies on the cytological changes in the eggs of *Toxopneustes* developing parthenogenetically by the Loeb method.

In the section for systematic zoology of the vertebrates one of the most interesting exhibits was that by Sclater of the skull and a portion of the skin of the newly discovered *Okapia*, a giraffine animal closely related to the extinct *Helladotherium* and obtained in the Urganda district by Sir Harry Johnston. The papers and demonstrations in the section for invertebrata were numerous, and it is impossible to refer to more than a few of them. Most noteworthy was perhaps a magnificent collection of Hexactinellid sponges obtained from the Japanese seas and exhibited by Professor Iijima, of Tokyo, while other papers of interest were by McBride on the development of *Echinus esculentus*, Apàthy on the visual cells of the Herudinea (both these with demonstrations), Hoyle on intrapallial luminous organs in the Cephalopoda and Simroth on the digestive canal of the Mollusca. The section on nomenclature devoted a considerable portion of its time to a consideration of the report of the commission proposed at the last Congress and appointed a committee to codify the rules as they now exist.

The arrangements for the meeting were admirably carried out. Through the courtesy of the president of the Reichstag the sessions of the Congress were held in the Reichstag building and everything was done to make the meeting enjoyable in every way. The death of the Empress Frederick naturally cast a gloom over the city and entailed considerable alterations in the program of excursions and festivities which had been planned by the committee, but withal they were fully successful in their efforts to make the meeting both intellectually and socially enjoyable for all those in attendance.

The next Congress will be held in Berne, Switzerland, in 1904, and Professor Studer, of Basel, was unanimously chosen as president-elect.

J. P. McM.

SCIENTIFIC BOOKS.

Annals of the Astrophysical Observatory of the Smithsonian Institution. Vol. I. By S. P. LANGLEY, Director, aided by C. G. ABBOT. Washington, Government Printing Office.

During the ten years of its existence the Smithsonian Astrophysical Observatory has been almost entirely devoted to the prosecution of a single research—a continuation of one begun some years ago by Professor Langley at Allegheny—namely, the production of a map of the absorption lines in the infra-red solar spectrum which would be in some measure comparable as regards completeness and precision with those of the visible region produced photographically with the aid of the grating. Besides this main research—and carried out largely since its completion—several subsidiary researches have been undertaken, one of which, to be mentioned later, is of particular importance.

If we represent the solar radiation by an energy curve, in the usual manner, in which ordinates are proportional to radiant energy, and abscissæ to wave-lengths, the selective absorption of the solar and terrestrial atmospheres will be indicated by depressions in the curve, whose depth and width will show the intensity of the absorption and the extent of the spectral region affected by it. In the visible region, of course, the absorption will be indicated by a great number of more or less sharp, close-packed depressions, corresponding to the great number of visible 'lines.' It has been found that, besides broad regions of general absorption previously noted by Langley and others, the infra-red spectrum is also affected by similarly sharp selective absorption, producing 'lines,' and as has been said, this main research is devoted to the mapping of

these 'lines'—that is, to the accurate determination of the details of the infra-red energy curve. It is noticeable that most of the effort has been put upon the measurement of the abscissæ of the curve (*i. e.*, wave-lengths), the ordinates being considered for the present of secondary importance; and no determination of the radiant energy in absolute measure has been attempted.

The problem can be considered as made up of two distinct parts: first, the production of a sufficiently intense, pure and well-defined solar spectrum by means which permit of the direct or indirect measurement of wave lengths; second, the detection of absorption lines in a region of this spectrum quite beyond the range of visual or even special photographic processes, and in a manner which will result in the precise location of these lines in the spectrum and in the approximate determination of their intensity and character. As a means of producing the spectrum the grating, on account of loss of energy, was necessarily discarded in favor of the prism; of glass for the shorter wave lengths, of rock salt for the longer. The observatory possesses undoubtedly the finest specimens known of the latter substance; one in particular, from the salt mines of Russia, in the form of a 60° prism with faces 13 cm. wide and 19 cm. high, having been used in the present research. The spectroscope as finally used was of the extremely convenient fixed-arm type described by Wadsworth (*Phil. Mag.*, '94) combined with a very ingenious collimating system of cylindric mirrors, due to Mr. Abbot, which enabled a slit of sufficiently small angular width to be used, while at the same time the linear width could be so great (over 0.2 mm.) that the loss of energy by diffraction at the slit was avoided. The refinement of the apparatus is shown by the fact that in the region of wave-lengths $\lambda < 2.5\mu$, a slit image of angular width $1''.5$ could be used with a bolometer of angular width $1''.2$, while for longer wave-length the values $4''.5$ or $9''$ and $3''.4$ respectively were necessary to obtain proper deflections. The Rayleigh formula for visual spectroscopic resolving power indicates that with the prism used some 1,300 lines might be detected in the region between $\lambda = .76\mu$ and $\lambda = 5.3\mu$. It is here shown that by the use of instruments of detection other than the eye the resolving power might be different and possibly greater than that given by Rayleigh's formula; and apparently this limit has been exceeded in practice. With the prism spectroscope, in order that the wave-length corresponding to a particular position in the spectrum may be known, the angle of the prism and its dispersion curve must be known; the former was determined with great care from time to time during the progress of this work, and a full discussion is given of the methods used, and of the precautions necessary when—as seems usually to be the case with rock-salt—the prism faces are curved; while the determination of the dispersion curve formed the principal subsidiary research.

As regards the method of detecting the lines, the instrument chosen was, naturally, the bolometer which for such purposes, where a linear form is essential, possesses decided advantages over any other form of radiation measurer yet devised. Instead of the usual visual observation of the motion of the spot of light reflected from the galvanometer mirror, produced by changes in the radiant energy falling on the exposed bolometer strip, a method of photographic registration was used. The spot of light fell upon a vertical photographic plate which was given vertical motion so connected mechanically with the motion of the spectrometer that each position of the plate corresponded to a definite position of the bolometer in the spectrum. The spot of light therefore occupied at any instant a position on the plate such that its one coordinate was proportional to the radiation striking the bolometer, and its other to the position of the bolometer in the spectrum; it therefore traced out the energy curve above referred to, except that the abscissæ were proportional not to the wave-length, but to the deviation produced by the particular prism used. In the form of fixed-arm spectroscope here used, the only moving part is the central table carrying the prism and a pane mirror suitably placed; if the table is given a uniform rotation, the angular motion of the spectrum past the fixed bolometer strip will be uniform also, and twice as rapid, and the particular wave-length in focus on the bolometer at any instant will have

passed through the prism at minimum deviation. The rotation of the prism corresponding to the entire range of wave-lengths here studied is less than 1° with the rock-salt prism—and hence it is necessary to be able to determine the angular position of the prism with rather unusual accuracy if the position of the bolometer in the spectrum (*i. e.*, the wave-length) is to be accurately known. The aim has been to have the maximum error in a single determination of the position of the bolometer in the spectrum not greater than $0''.6$, corresponding in the usual case to 0.1 mm. on the photographic plate. The critical part of the mechanical connection between the spectrometer and plate is a worm and wheel-segment by Warner and Swasey, which is so good that the above rigorous conditions can probably be nearly satisfied. When in use the spectrometer and plate are moved uniformly by clockwork which is, however, quite independent of the accurate mechanical connection between them, so that its errors do not enter. The photographic energy curve thus obtained by the motion of the spectrum past the bolometer strip will show besides the depressions due to the absorption lines sought, many other depressions and irregularities due to disturbances of a mechanical, electrical, magnetic or thermal nature, and a large part of the work has been an attempt to reduce to a minimum these accidental disturbances in order that the depressions in the curve due to real lines might be more clearly identified. It is impossible to consider here the causes of these irregularities—some coming from the bolometer circuit, some from the galvanometer, some from the battery, or the steps which have led to the gradual reduction of them, though these fill what is in some ways the most interesting chapter. Suffice it to say that careful comparison of a number of the best curves, or bolographs as they are called, has resulted in the more or less certain identification of over 700 lines in the region from $\lambda = 0.76\mu$ to $\lambda = 5.3\mu$ whose wave-lengths are determined with a mean probable error of two or three Ångstrom units, the results being given in tables, containing also indications as to the character and grouping of the lines. A graphic representation is also given in the form of line spectrum maps, both normal and prismatic, either drawn by hand from the tabulated results, or transformed in a semi-automatic way from some of the curves themselves. This process seems of doubtful value, however, as the line-spectrum conveys in reality less information than the curves themselves, while it is apt to produce a false impression of authenticity. Curves and tables are also given illustrating the changes which occur, seasonal and otherwise, in the intensity of many infra red absorption lines; changes whose existence is here definitely fixed, but which will have to be further investigated before their cause can be assigned.

The most important subsidiary research has been the determination of the dispersion curves of rock-salt and fluorite; the former by direct comparison (so to speak) with a grating, the latter by comparison of fluorite bolographs with rock-salt bolographs of the solar spectrum, and measurements of the deviation of the same lines in both. Langley's early method was substantially repeated here in the work with rock-salt, and is briefly as follows:

Radiation from whatever source is used falls first upon the slit of a Rowland concave grating spectroscope, the eyepiece of which is replaced by a second slit; the radiation passing this second slit, from the grating, goes through the optical train of the prism spectroscope and is brought to focus at the proper place in the dispersion spectrum of the particular prism used. If the grating is set so as to let through the second slit light of a known (visible) wave-length in (say) the 3d order spectrum, waves of $\frac{3}{2}$ and 3 times this length will also pass through, belonging to the 2d and 1st order spectra. Hence in the dispersion spectrum of the prism there will be three distributions of energy, more or less sharp according to the widths of the two slits; and if a bolograph of this spectrum is taken in the usual way, three maxima will appear, separated by regions indicating no radiation. If on the same plate a record of the 'A' line is made, the relative deviation of the maxima (due to known wave-lengths) with respect to the 'A' line, can be determined by measurement of the plates. Such records, combined with the determination of the absolute deviation of the 'A' line, and of the angle

of the prism, gave the data for plotting the dispersion curve of rock-salt. The results, exceeding in accuracy any heretofore obtained, and which will be of the greatest value to other investigators using rock-salt dispersion for infra-red work—are given in several convenient forms, most conveniently, perhaps, in the shape of a very large scale curve, extending between the limits $\lambda = 0.5\ \mu$ and $\lambda = 6.5\ \mu$, from which indices of refraction can be read off to 0.000002, and for which the probable error lies usually between 0.000009 and .000018. The dispersion curve of fluorite is given on the same scale between the limits $\lambda = .75\ \mu$ and $\lambda = 3.5\ \mu$. From the data for rock-salt have been calculated the five constants of the Ketteler dispersion formula, which differ quite noticeably from those calculated by Rubens and Trowbridge for a longer wave-length interval; but the differences between the observed and computed values of index of refraction are hardly greater than the probable errors of deviation, except for the longest wave-lengths. Accurate comparisons have also been made of the dispersion of three rock salt prisms which confirm the view that rock-salt as found in nature is in one respect of great optical uniformity, so that accurate determinations of indices of refraction for one prism can be safely applied to another for the purpose of determining wave-lengths; an extremely fortunate circumstance.

It is impossible to do more than mention some of the lesser pieces of work here recorded—such as the determination of the energy curves of various incandescent mantles; tests of the accuracy or constancy of the bolometer, which unfortunately do not touch the most difficult point, *i. e.*, constancy as regards sensibility for long time intervals; and a study of the minute structure of the infra red absorption band 'ω_1.' A considerable space is, appropriately, devoted to the discussion of errors, and to methods for overcoming difficulties inherent in bolometric work; of which the most troublesome are undoubtedly 'drift,' or the continuous change in the zero position of the galvanometer spot of light, and the more or less rapid periodic changes of zero, or 'wiggle.' The various precautions taken, which have finally almost eliminated the drift and greatly reduced the 'wiggle,' are dealt with in full; few of them altogether new perhaps, but certainly applied here with greater completeness and care than has been done elsewhere. The detailed consideration of manipulation and construction will be of great value to others engaged in similar work. In particular should be mentioned the study of the behavior of rock-salt prisms under conditions of rising temperature; the question of the construction of linear bolometers, in which such skill has been attained, and of the design of balancing bridges; and the full discussion of the adjustments of the fixed-arm spectroscope. In the chapter on the galvanometer will be found a useful table of the computed axial magnetic force produced by galvanometer coils of various resistances, wound either with a single size of wire or with different combinations of three sizes, which not only shows clearly the advantage of sectional winding, but will be a valuable aid in the design of galvanometers. The use of the Ayrton-Mather scale for expressing galvanometer sensibilities, now so generally adopted, would have rendered easier the comparison of the observatory instrument with others.

The valuable and interesting material, which it has been here attempted briefly to summarize, is the result of about nine years of work, involving the labors, successively, of Dr. Hallock, Mr. Wadsworth, Mr. Child and, for a longer time, of Mr. Abbot and Mr. Fowle, all under the direction of Professor Langley. From time to time statements of the progress of the work have been made by Professor Langley, and some special points considered in papers of Mr. Wadsworth, Mr. Abbot and Mr. Fowle, but the results now made public are so interesting and so important to all engaged in similar work that it is to be hoped that in the future conditions affecting publication by the government may allow more frequent and less delayed reports from this observatory, which is unique in its possibilities for the highest class of work with radiant energy.

C. E. MENDENHALL.

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